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June 20, 2017

Marlene H. Dortch
Secretary
Federal Communications Commission
445 12th Street S.W.
Washington, DC 20554

Re: Notice of Ex Parte Presentation Regarding the Modification Applications of Ligado Networks, LLC: IB Docket Nos. 11-109 and 12-340; RM-11681; IBFS File Nos. SES-MOD-20151231-00981, SAT-MOD-20151231-00090, and SAT-MOD-20151231-00091

Dear Ms. Dortch:

On Friday, June 16, 2017, representatives of the aviation and aerospace communities – specifically representatives of Aviation Spectrum Resources, Inc. (“ASRI”), Airlines for America (“A4A”), and Helicopter Association International (“HAI”) and a representative of Aerospace Industries Association (“AIA”) (collectively, the non-Commission participants referred to herein as the “Representatives”) – met with staff from the Wireless Telecommunications Bureau, the Office of Engineering and Technology, the International Bureau, and the Public Safety and Homeland Security Bureau of the Federal Communications Commission (the “Commission”) to discuss the above-referenced license modification applications of Ligado Networks, LLC (the “Applications”). A list of the meeting participants is appended hereto as Attachment A. ASRI, A4A, and HAI were members of the Joint Aviation Parties and the Joint Aviation Reply Commenters raising concerns about Ligado’s proposals in comments and reply comments submitted in the above-referenced dockets and files in response to the Commission’s April 22, 2016, Public Notice.¹ AIA filed both comments in response to the Public Notice and reply comments in these proceedings as well.

¹ *Comment Sought on Ligado’s Modification Applications*, Public Notice, IB Docket Nos. 11-109 and 12-340 (rel. Apr. 22, 2016) (“Public Notice”)

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The Representatives countered the false notion raised in recent filings by Ligado, most recently its June 5, 2017, *ex parte*, that all opposition to its proposed modifications have been fully addressed and consensus reigns.² The Representatives underscored that the issues the aviation and aerospace communities raised earlier in their earlier comments and *ex parte* submissions in these matters regarding Ligado's proposals have largely gone unresolved since last summer. The Representatives explained that they are not opposed to the sort of services that Ligado wants to provide *per se* – indeed, they recognize the prospective value of the solutions that Ligado claims it will offer to even the aviation and aerospace industries – but noted that, because of the paramount importance of safety of flight, the aviation and aerospace industries maintain grave doubts about Ligado's chosen location in the radio frequency spectrum and how Ligado plans to offer its services. The open issues turn on the serious potential for spectrum incompatibility affecting safety of flight between Ligado's proposed operations and certified aviation and non-certified precision GPS receivers on aircraft, aviation safety satellite communications ("SATCOM") in adjacent 1600 MHz bands, and reception of weather satellite data broadcast in and adjacent to the 1675-1680 MHz band. In the June 16 meeting, the Representatives focused exclusively on GPS and SATCOM issues.³

The Representatives discussed the serious concerns with Ligado's proposed solution for certified aviation GPS receivers, namely, protection from harmful interference pursuant to a technical criterion of 250 feet horizontally from a Ligado antenna and 30 feet above the antenna. They underscored that such a solution would fail to protect the safe navigation of helicopter operations in many common scenarios. Mr. Chris Martino of HAI explained that helicopters depend on GPS due to their regular operation at low altitudes. He noted that, unlike fixed-wing aircraft, helicopters conduct most of their operations below 5,000 feet, and very commonly below 500 feet, especially in emergency situations such as medical evacuations, firefighting, and surveillance, during which helicopters frequently land or take off in unprepared sites as well as

² See from Gerard J. Waldron, Covington & Burling LLP, Counsel to Ligado Networks LLC, to Marlene H. Dortch, Secretary, Federal Communications Commission, IB Docket Nos. 11-109 and 12-340; IBFS File Nos. SES-MOD-20151231-00981, SAT-MOD-20151231-00090, and SAT-MOD-20151231-00091 (filed June 5, 2017) at 1-2 ("The United States Government should recognize [the] consensus of industry and scientific opinion expressed in this proceeding and put this vital mid-band spectrum to work in building our 5G and IoT future").

³ The Representatives indicated that they intended to address the issues surrounding Ligado's Petition for Rulemaking for a proceeding to consider adoption of rules to make 1675-1680 MHz available for commercial mobile operations at a separate time, although they noted that the issues that Ligado wishes to defer to a rulemaking regarding its proposed use of that band are sufficiently briefed that they should be addressed *before* any Commission decision is made to proceed with a rulemaking and additional rounds of comment. If these questions cannot be resolved or further refined based on the record compiled to date which reflects broad opposition to Ligado's plans from many sectors of government and the economy – the initiation of a rulemaking proceeding would be redundant and inefficient.

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on or in roads, parking lots, and fields. Such flight profiles often obstruct other ground based navigational aids, and GPS is therefore often the only external navigational data available. Despite pilots operating using Visual Flight Rules (“VFR”) at these distances, GPS reception is still critical for terrain avoidance and position reporting with other air users. In addition, visual navigation is not always possible or reliable, especially at night and in bad weather. Mr. Martino emphasized that the concern is very real given that Ligado estimates as many as 10,000-20,000 antenna sites.

The Representatives explained that the results from the review by Special Committee 159 (“SC-159) Radio Technical Commission for Aeronautics (“RTCA”), requested by the Federal Aviation Administration (“FAA”) of the Ligado-conducted studies to certified aviation GPS receivers of the potential for interference Ligado plan demonstrated numerous lingering problems. The December 2016 summary report from SC-159 Working Group 6 (“WG6”) indicates that the results of the review, at best, from Ligado’s perspective, were incomplete and inconclusive – but only because Ligado stood in opposition to other participants.⁴ WG6 could not achieve consensus on many aspects of the technical analysis.⁵ The participants (with the exception of Ligado) also stressed the importance of FAA or RTCA conducting further reviews of the tools and numbers behind the Ligado results.⁶ As explained at the meeting, to the Representatives knowledge, based on communications with FAA officials, the FAA, contrary to Ligado’s claims in its June 5 *ex parte*, has never endorsed the Ligado proposal or its solutions to afford protection against harmful interference to certified aviation GPS receivers.

The Representatives also discussed the importance of fully understanding the potential impact from Ligado handsets on precision and other non-certified GPS receivers before action is taken. They emphasized the importance of examination of the yet-to-be-released Department of Transportation (“DOT”) Adjacent Band Compatibility (“ABC”) assessment which comprehensively analyzed this potential. The Representatives explained that the ABC assessment accounts for the full range of ways in which non-certified receivers are used by aviation, unlike the studies Ligado commissioned or relies upon which focus on the position parameter but ignores key metrics such as velocity. The DOT initial results indicate, as the Representatives explained, that serious concerns remain regarding the potential impact from Ligado’s proposed operations on important non-certified receivers used by aviation (let alone in other contexts).

⁴ Summary of Ligado Proposal Review by RTCA SC-159, WG6, as approved by RTCA SC-159, RTCA Paper No. 333-16/SC159-1055 (dated December 13, 2016) available at https://www.rtca.org/sites/default/files/sc-159_wg6_response_ligado.pdf. (attached hereto as Attachment B)

⁵ See discussion in *id.* at 3-5.

⁶ *Id.* at 6.

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Turning to the issue of SATCOM, the Representatives explained that they generally support the concerns raised by Iridium in these proceedings and its conclusion that Ligado's Ancillary Terrestrial Component ("ATC") handsets present a real danger of out of band interference to SATCOM. Aviation is concerned about the potential impact on both Inmarsat and Iridium systems, and ASRI is looking closely at the publicly available spectrum compatibility analyses of both Ligado and Iridium filed into the record. ASRI is considering a response within the next few months.

At the meeting, the Representatives explained that the interference to SATCOM is a problem with a potentially wide impact. They noted that it is a misconception that SATCOM operations need to be protected only over the oceans. As an initial matter, SATCOM systems must be tested on the ground successfully before takeoff, since it is too late to find that the systems do not work, if that is the case, once the aircraft is entering oceanic airspace. Additionally, SATCOM is used in other situations as well, such as relaying of aircraft health data during all phases of flight, and is an important back-up capability if there a loss of VHF radio connectivity while in the United States.

The Representatives expressed their concern about the potential impact to the Inmarsat system, especially since, in December 2015, Inmarsat filed with the regulator in the United Kingdom concerns about compatibility with Ligado (at separation distances of over 30 miles).⁷ It has not been clarified why Inmarsat's concerns would not be similar in the United States since SATCOM receivers are standardized worldwide. While Inmarsat has claimed in the record of IB Docket Nos. 11-109 and 12-340 that there is an interoperator cooperation agreement between it and Ligado "that paves the way for Ligado to develop its L-band ATC network while allowing Inmarsat to continue providing services and innovating in the L-Band" that document has not been made available to the Commission or the public in these proceedings. Nor has the technical or operational basis for that arrangement ever been explained.⁸ The Representatives asserted that such non-public information should not be the basis for a Commission decision that could, as a general matter, adversely impact all members of the flying public. Indeed, Inmarsat late last year disclosed that its "interference mitigation strategy [with Ligado] may not be successful."⁹

Finally, the Representatives raised the concerns with any necessary retrofit of aircraft with new SATCOM transceivers. The cost to retrofit the airlines with new SATCOM terminals

⁷ Inmarsat Response, OfCom Consultation Document: New Spectrum For Audio PMSE (Dec. 18, 2015). Available at <http://stakeholders.ofcom.org.uk/binaries/consultations/newspectrum-audio-PMSE/responses/Inmarsat.pdf>

⁸ See Reply Comments of Inmarsat Inc., IB Docket Nos 11-109 and 12-340 (filed June 21, 2016), at 1-2.

⁹ Inmarsat Group Limited – Interim Results 2016 – Supplemental Disclosure 14 September 2016 at 6, available at <http://www.inmarsat.com/wp-content/uploads/2016/09/Supplemental-disclosure-document-14-September-2016.pdf>

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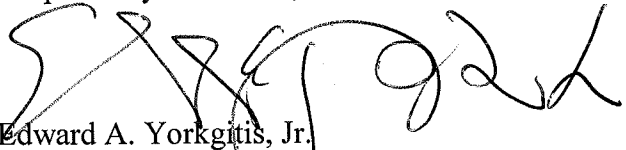
would be huge, if this is even possible for certain types of interference. Mr. Robert Ireland of A4A suggesting that the total cost of retrofitting, including development and servicing, could be in near a billion dollars. Who would pay for the retrofit and how that would be done equitably if necessary is a subject that has not even been broached by Ligado with the airline industry. In addition, any retrofit would take a considerable amount of time and present logistical challenges that could adversely affect air travel: new FAA certifications would be required (i.e., new Minimum Operational Performance Standards ("MOPS")), design and development of the new equipment would have to occur followed by production, and then implementing the retrofit would require scheduling aircraft to be taken out of fleet operations temporarily as the work is done and would likely extend over several years.

In closing, the Representatives reiterated their position that the Commission should not move on Ligado's proposals until the many remaining open issues – issues that Ligado has mischaracterized in its *ex parte* presentations as successfully closed by consensus among the potentially affected parties – are adequately addressed.

This *ex parte* notice and its attachments are being filed with the Office of the Secretary of the Commission as require by Section 1.1206 of the Commission's rules.

Please direct any questions to the undersigned.

Respectfully submitted,



Edward A. Yorkgitis, Jr.
Counsel for Aviation Spectrum
Resources, Inc.

Cc: Charles Mathias
Aalok Mehta
Ronald Repasi
Paul Murray
Michael Ha
Robert Nelson
Chris Anderson
Alex Vetras

Attachment A

Attendees at ex parte meeting on June 16, 2017

Aviation and Aerospace Representatives:

- Cortney Robinson, Aerospace Industries Association
- Robert Ireland, Airlines for America
- Andrew Roy, Aviation Spectrum Resources, Inc. ("ASRI")
- Edward A. Yorkgitis, Jr., Kelley Drye & Warren LLP, counsel for ASRI
- Chris Martino, Helicopter Association International

Federal Communications Commission Representatives:

- Charles Mathias, Wireless Telecommunications Bureau
- Aalok Mehta, Wireless Telecommunications Bureau
- Ronald Repasi, Office of Engineering and Technology
- Paul Murray, Office of Engineering and Technology
- Michael Ha, Office of Engineering and Technology
- Robert Nelson, International Bureau
- Chris Anderson, Public Safety and Homeland Security Bureau
- Alex Vetras, Wireless Telecommunications Bureau (summer law intern)



**Summary of Ligado Proposal Review by
RTCA SC-159, WG6
as approved by RTCA SC-159
December 13, 2016**

RTCA Paper No. 333-16/SC159-1055

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WG-6 Summary and Response

In the 19 Oct. 2016 letter to Margaret Jenny, President of RTCA, Inc., the FAA requested that the RTCA review two documents that are part of Ligado's proposals for ensuring compatibility between its handsets and aviation certified GPS receivers [1] and its terrestrial downlink stations and aviation certified GPS receivers [2].

RTCA, in turn, asked SC-159 to review the technical aspects of the proposal while the TOC (Tactical Operations Committee) would address the operational aspects of this proposal. The goal of this review within SC-159, per guidance from the FAA, is to provide technical feedback on the assumptions and methodologies espoused by Ligado in its assessment of the compatibility between Ligado Downlink/Uplink and certified aviation GPS solutions.

Multiple telecons were held (10/28/16, 11/4/16, 11/10/16, 11/17/16, 11/22/16, 11/30/16, 12/2/16, 12/5/16) to disposition comments from SC-159, WG6 (which addresses GPS interference characterization within SC-159) on the Ligado proposal. As part of this review, 34 comments were compiled from multiple WG6 participants. These comments [3] are provided in the form of a comments resolution matrix for further review. In response to comments on the proposal, Ligado has provided additional information for review [4][5][6][10]. In addition, some of the original commenters then provided follow on responses to specific comment items which are included [7][8] for further reference.

Pursuant to discussions with stakeholders from Ligado and the aviation community with WG6, some of the comments posed were dispositioned with consensus. However, a total of 15 other comments for which WG6 could not establish consensus are highlighted for reference in the comments matrix [3]. No formal comments were received on the Ligado Uplink Proposal [1].

Broadly speaking, the following are the items which WG6 did not achieve consensus:

1. RFI Propagation (Channel) Model: Ligado's position is that a deterministic (vs. probabilistic) approach on channel modeling is more appropriate because its analysis shows that a probabilistic model results in anomalous results (e.g. showing increased rare power RFI levels from base stations that are farther away from the helicopter relative to nearby base stations, which does not comport with RFI physics) for the aggregate RFI contribution from adjacent base stations. If a probabilistic approach is taken, Ligado urges that a conditional probability approach should be used in lieu of a per event characterization as the exposure probabilities are much smaller (due to substantial base station EIRP reduction). The other WG6 participants' perspective is that the probabilistic approach presented in the marked-up original FAA ABC study methodology document [9] in fact works well and must be used for the cases in the Ligado proposal [2] under review to comply with the pertinent safety standards. These issues are discussed in further detail in comment 23.

2. Safety margin: Ligado's perspective is that, in a deterministic model, a 6 dB safety margin is appropriate for evaluating helicopters in level flight. Ligado also states that 2 dB safety margin is appropriate for evaluating helicopters in a banked or pitched attitude, as it is highly unlikely (based on Ligado's conversations with HEMS operator Metro Aviation) that helicopters would be in such a position, close to ground level and travelling at the speed required to even maintain a 25° bank/pitch – all in such close proximity to an obstruction. Additionally, Ligado states that in such events, these aircraft are being operated under VFR and not relying on GPS for obstacle and obstruction clearance and avoidance. The other WG6 participants' perspective is that the probabilistic approach with mean and rare RFI limits (6 dB and 2 dB, respectively, below the MOPS adjacent band tracking threshold) must be applied simultaneously on a per-event basis independent of aircraft attitude to comply with the relevant FAA recommendations; otherwise, an appropriate safety margin is not maintained. The per-event probability may not be apportioned further as a per exposure conditional probability for the same reasons. Other WG6 participants would like to clarify that GPS is being used or relied upon for obstacle and obstruction clearance and avoidance under VFR conditions (HTAWS). These are discussed in further detail in comments 7, 12, 24.
3. 250 ft. standoff radius partially based on OOB: Ligado proposes a 250' radius cylinder around towers for the purposes of modeling RFI. They based this proposal on their assessment of previous FAA proposals, consultations with industry experts and an assessment of the existing RF environment. In its assessment of the RF environment, Ligado refers to a technical analysis of the out-of-band emissions of other FCC-licensed wireless services, and concludes, based on information it has compiled from publicly-available FCC information, that emissions into the GNSS band from other sources are in excess of the RTCA criteria and that interference could be observed by certified GPS devices operating within 250 feet of a cell site. The other WG6 participants' perspective is that, after further discussion with Ligado, there is no conclusive evidence from the data presented that these higher levels of unwanted emissions from PCS and other sources exist in the GNSS band. WG6's assessment of the data presented by Ligado [6] is that this information is based on FCC filings predicated on conducted emissions testing and not necessarily reflective of the RFI environment as seen in the GNSS band. The conducted emission data in the test reports cited as evidence by Ligado are the result of the test equipment noise floor. These are discussed further in Comments Matrix lines 3, 22, 32, 35.
4. Mechanism for Co-ordination of a potential Ligado deployment: Ligado has stated that it will ensure its network fully meets FAA conformance standards for instrument approaches to airports and heliports. Ligado further states that it has focused its efforts on developing the overall conformance methodology and will create its compliance plans once that methodology has been approved by the FAA. The other WG6 participants expressed concern that it is not clear how such conformance will be enforced and with uniform adherence to the FAA's obstacle

clearance criteria achieved for existing and future instrument procedures and related 14 CFR 77 requirements. Other WG6 participants also propose that the FAA recommend to the FCC that base station power level monitoring relative to the required RFI limit by Ligado's network operations center should be included as a license condition. This is discussed further in comments 6, 26, 35.

5. Determination of aggregate RFI backoff: Ligado provided an aggregate power backoff analyses based on deterministic path loss modeling. Ligado's perspective is that base station design best practices would require that macro cells, typically using taller antennas, will have larger inter-site distances than small cells using shorter antennas in order to avoid self-interference. Ligado believes any license restrictions should be deferred to the regulatory bodies. The other WG6 participants believe that the aggregate power backoff analyses provided by Ligado in its proposal is not expected to address all combinations of possible base station rollouts. To address this concern, one proposal from other WG6 participants is to have a license condition that restricts antenna base station configuration as a function of ISD. This is discussed further in comments 7, 18 and 25.
6. Evaluation of GPS signal acquisition, initialization and power up needs in the vicinity of a Ligado Downlink base station: GPS Acquisition was not stated as a requirement per the original FAA tasking letter (2014 letter and RTCA response in 2015). Ligado believes the difference between acquisition and tracking thresholds do not create additional risk to safe helicopter operations. Based on Ligado's discussions with Metro Aviation, an HEMS operator, Ligado says there is an extremely small likelihood of a helicopter landing in close proximity to a transmitter that would create power levels on the ground that would interfere with GPS acquisition following a shutdown and restart of the aircraft. In the extremely remote chance that such a situation did occur, normal IFR operating procedures should provide the aircraft adequate time to reacquire prior to entering IMC conditions. The other WG6 participants' perspective is the following: If the power levels for the current Ligado proposal were to be lowered to support a standoff distance of 250 ft. around a base station, this deployment configuration is expected to pose a different set of impacts to rotary wing and UAV operations. For example, this could include impacts to GPS initialization, power-up, and satellite acquisition for EMS helo operations. Per RTCA/DO-229D MOPS, certified safety of life GPS receivers are required to establish initial acquisition within 5 minutes from power up. This time window may result in inadequate operational capability under IMC conditions if the helo operator were to commence operations prior to GPS signal acquisition. Analysis of the acquisition should be performed using the compatibility criterion that the mean RFI power should be such that the probability of exceeding a level 6 dB below the RTCA MOPS adjacent band threshold is less than 1×10^{-3} . This is discussed further in comments 33 and 34.

7. Review of the tools and the numbers behind the final results: Ligado's perspective is that this is not in the scope of the current review but has agreed to share the tools used after the evaluation methodology has been finalized by the FAA. The FAA clarified that the specific tools/numerical results were not within the scope of the requested review. The other WG6 participants believe that it is necessary to review the tools and final numbers before RTCA / or the FAA's evaluation is finalized. Given the complexity of the algorithms and the potential for implementation error, other WG6 participants believe, it is important for aviation safety to have an FAA or RTCA replication of the results presented by Ligado, and a review of its specific implementation of the algorithm. This is discussed in comment 9.

References

1. Ligado Report on Compatibility of Ligado Networks' Uplink Emissions with FAA Requirements for Certified Aviation GPS Receivers
2. A method for calculating adjacent band RF interference power received by a certified aviation GPS receiver from proximate terrestrial base stations - Ligado
3. Ligado Proposal Review - Comments Matrix - Final - TO SC-159.xls – Attachment 1
4. Ligado Responses to WG6 11-8-16.pdf
5. Ligado Responses to WG 6 - Release 2 11-16-2016.pdf
6. Assessment of OOB from other wireless carriers (Updated Nov 8, 2016).pdf - Ligado
7. Garmin Comments on Ligado Responses 11-16-2016.pdf
8. Reference Comments in Item 35_v1.doc – Larry Chesto
9. FAA GPS Adjacent-Band Compatibility Study Methodology and Assumptions, RTCA Paper No. 095-15/SC159-1040 – SC-159 Mark-Up
10. Ligado WG-6 Responses 12-2-16.pdf

Appendix A: Comment Matrix

Comment ID	Author	Section	Page	Comment	Suggested Resolution	Resolution	Action History/Description	Action Status
2	John Foley	General (applies to all comments)		Garmin's settlement agreement with Ligado provides that nothing in that agreement constitutes an endorsement of Ligado's proposed network. The agreement, however, does include restrictions on Garmin's ability to object to certain matters. Accordingly, Garmin's submission with respect to this Ligado Downlink Assessment matrix relates solely to interference issues regarding certified Garmin GNSS aviation equipment caused by Ligado's use of the 1526-1536 MHz spectrum. A short statement noting this point is included in Garmin's matrix entries.				
3	John Foley		2	<p>The submission relates solely to certified Garmin GNSS aviation equipment:</p> <p>Ligado refers to a technical analysis of the out-of-band emissions of other FCC-licensed wireless services, but does not provide any details of this analysis besides the conclusion the interference would be observed by certified GPS devices operating within 250 feet of a cell site.</p> <p>This conclusion is provided as a justification for a 250 foot radius standoff cylinder around a Ligado base station.</p>	Provide the details of this technical analysis for RTCA review.	Consensus has not been achieved on this item. Ligado perspective: Evidence suggests that emissions into the GNSS band from other sources are in excess of the RTCA criteria. WG6 perspective: There is no conclusive evidence from the data presented that we have these higher levels of OOB from PCS and other sources in the GNSS band.	1) Ligado to provide additional references in relation to this query (Presentation is in record, Ligado to send WG6 a copy of the same), 2) Ligado to provide information on noise floor of OOB from base stations into the GNSS band. Ligado provided information on this on 11/8/16. Garmin responded to the same on 11/16/16.	WG6 to provide feedback to RTCA per the resolution column

4	John Foley	Introduction	2	<p>The submission relates solely to certified Garmin GNSS aviation equipment:</p> <p>Ligado asserts that rotorcraft operators do not use certified GPS equipment when operating in close proximity to structures of any kind. This assertion is used as a justification for a 250 foot radius standoff cylinder around a Ligado base station.</p> <p>This assertion ignores the presence of power lines that are within a base station's 250 foot radius standoff cylinder. These power lines are not easily seen in daylight VFR conditions. Some HTAWS equipment provides additional GPS-based safety-enhancing power-line alerting to warn pilots of such obstacles.</p>	The assessment of the suitability of a 250 foot radius standoff cylinder around a Ligado base station should consider risks imposed by power lines and other hard-to-see obstacles that are within the standoff cylinder and for which Garmin certified equipment provides warnings.	This is an operational concern and is expected to be addressed by the TOC	<p>1) How close to the power lines can the equipment operate - John Foley, 2) How close to the other cell towers can the equipment operate - John Foley. Garmin responded to the same on 11/30/16:</p> <p>1) Garmin is not aware of any GPS interference issues arising from proximity to power lines. The following two papers describe analytical and test results that confirm that power lines do not impact GPS receiver performance:</p> <p>i. J. Michael Silva, Robert G. Olsen, "Use of Global Positioning System (GPS) Receivers Under Power-Line Conductors", IEEE Transactions on Power Delivery, Vol. 17, No. 4, October 2002</p> <p>ii. J.B. Bancroft, A. Morrison, G. Lachapelle, "Validation of GNSS under 500,000 Volt Direct Current (DC) Transmission Lines", Computers and Electronics in Agriculture, Volume 83, April 2012. http://plan.geomatics.ucalgary.ca/papers/bancroftetal2012-500kvinterference%20planweb%2028feb12.pdf</p> <p>2) Regarding the operation of GPS receivers in proximity to other cell towers, any interference to GPS receivers from cell towers would be dependent on the actual emissions of those cell towers relative to the RFI susceptibility requirements defined in the applicable TSOs and RTCA MOPS.</p>	WG6 to provide feedback to RTCA per the resolution column
5	John Foley	Introduction	2	<p>The submission relates solely to certified Garmin GNSS aviation equipment:</p> <p>The proposed 250 foot radius standoff cylinder around a Ligado base station is very similar to the 500 foot radius exclusion zones originally proposed in the FAA Adjacent Band Compatibility Methodology.</p> <p>The 500 foot radius exclusion zones were evaluated by RTCA's Tactical Operations Committee and were found insufficient to avoid adverse safety and operational impacts to aviation.</p>	The 250 foot radius standoff cylinders should be evaluated for safety and operational impacts by the Tactical Operations Committee.	TOC will be reviewing this proposal. TOC plans to follow the WG6 timeline (Dec 15 feedback to FAA). This comment will be forwarded to the TOC for discussion. Consensus has not been achieved on this item.	This comment will be forwarded to the TOC for discussion	WG6 to provide feedback to RTCA per the resolution column

6	John Foley	Introduction	3	<p>The submission relates solely to certified Garmin GNSS aviation equipment:</p> <p>Ligado states that it will ensure its network fully meets FAA conformance standards for instrument approaches to airports and heliports.</p> <p>It is not clear how this will be enforced and uniform adherence to the FAA's obstacle clearance criteria achieved.</p>	Provide more details of the coordination process between Ligado and the FAA to ensure that Ligado tower placement will not violate approach and departure obstacle clearance requirements.	Clear Consensus has not been achieved on this item.	Ligado to provide a write up of their perspective on how this will be addressed. Ligado provided a response (11/8/16 - Ligado Responses to WG6 11-8-16.pdf) and Garmin provided feedback on this response (11/16/16 - Garmin Comments on Ligado Responses 11-16-2016.pdf).	<p>Both these responses are available for review on the workspace and will be attached as part of the final feedback from WG6.</p> <p>WG6 to provide feedback to RTCA per the resolution column</p>
7	John Foley	Methodology - Step 2	4	<p>The submission relates solely to certified Garmin GNSS aviation equipment:</p> <p>Ligado is proposing an additional 0.9 dB reduction in the base station EIRP to account for the estimated maximum aggregate power received from other base stations.</p> <p>This 0.9 dB reduction is proposed to be applied to all base stations regardless of the actual network deployment in the area. This blanket assumption only works if the analysis actually determines a worst case aggregate power that holds throughout the evolution of Ligado's network. While Ligado does propose a license condition to limit its intersite distance to ≥ 433 meters, it does not similarly propose to limit other network parameters such as antenna patterns and downtilt, limitations that are necessary.</p>	Need additional confirmation that the 0.9 dB reduction for aggregate power effects actually overbounds the future aggregate power accounting for variations in deployment pattern and antenna characteristics.	<p>Ligado: Using a conditional probability approach to address the 1e-6/hr case.</p> <p>WG6: The conditional probability approach does not apply in this case. The conditional probability assumption is not supported.</p>	<p>1) Ligado to provide rationale on deviation of methodology (from FAA recommendation) for assessment of 0.9 dB backoff. 2) rationale for the 0.9 dB back off value.</p> <p>Ligado provided a response on 11/22/16 - Please refer to "Ligado WG-6 Responses 11-22-16.pdf" for details.</p>	<p>Consensus has not been achieved on this item. Please see resolution column for details.</p> <p>This item will be shared with the TOC for consideration.</p>
8	John Foley	2.0	6	<p>The submission relates solely to certified Garmin GNSS aviation equipment:</p> <p>The Ligado proposal references the October 3, 2014 FAA ABC Methodology and Assumptions document.</p> <p>RTCA reviewed this document and provided feedback to the FAA that included proposed changes (RTCA Paper No. 095-15/SC159-1040 - SC-159 Markup).</p> <p>It is not clear that the prior RTCA feedback has been incorporated into Ligado's proposal.</p>	Clarify which version of the FAA methodology paper was used.	Clarification provided that the version used was the one that RTCA sent back to the FAA. This is the marked up version that RTCA sent to the FAA - Oct 3, 2014.		Item closed

9	John Foley	3.0	7	<p>The submission relates solely to certified Garmin GNSS aviation equipment:</p> <p>Ligado has developed a model to evaluate the transmit power and presumably has developed a set of computer tools to compute the maximum and aggregate RFI. Given the complexity of the algorithms and the potential for implementation error, it is important for aviation safety to have an FAA or RTCA replication of the results presented by Ligado, or a review of its specific implementation of the algorithm.</p>	FAA or RTCA should conduct an independent review of Ligado's tool set or corroborate the results generated from the tools.	RTCA to review methodology, approach and assumptions in the Ligado Proposal. Ligado to provide toolset to RTCA for review and feedback at a later point in time (Jan 2017). RTCA will have opportunity to weigh in on the tool set shared by Ligado.		Provide feedback from SC-159, WG6 per Resolution column
10	John Foley	3.0 item 1.b	7	<p>The submission relates solely to certified Garmin GNSS aviation equipment:</p> <p>There is no specification provided for the step intervals used to increase the antenna height for the peak RFI determination. The use of large steps may understate the peak RFI.</p>	Specify the step interval used to increment the altitude to determine the peak RFI.	1 meter step interval used		Item closed
11	John Foley	3.0 item 1.b	7	<p>The submission relates solely to certified Garmin GNSS aviation equipment:</p> <p>The methodology states that it is not necessary to check all the way up to the full height of the cell site as the power reduces monotonically above the helicopter height corresponding to maximum RFI.</p> <p>The base station vertical antenna pattern shown on page 26 does not show monotonically increasing gain below the peak gain value. There is ripple in the vertical gain pattern. An algorithm that stops at the first reduction in received RFI may miss the peak RFI.</p>	The evaluation of peak RFI should extend up to the full height of the standoff cylinder (with an appropriately small step size) to avoid incorrectly identifying the point of maximum RFI.	Assessment is being performed to the full height of the cylinder	Perform assessment to the full ht of the stadnoff cylinder	Item closed

12	John Foley	3.0 item 1.c	8	<p>The submission relates solely to certified Garmin GNSS aviation equipment:</p> <p>Table 1 specifies a lower Aviation Safety Margin for the 25 degree banking case, citing the FAA methodology and assumptions document.</p> <p>Appendix C of the FAA methodology and assumptions document does specify a 2 dB safety margin for the banking and pitch requirements.</p> <p>However, in section 2.1.1.1 of the FAA methodology and assumptions document, the 6 dB safety limit is specified. Additionally, the RTCA markup of the FAA Methodology and Assumptions document includes a new footnote #3 indicating that the 6 dB safety margin applies for aircraft and ground operations. Thus, the 2 dB margin for the 25 degree banking case appears inconsistent and needs clarification.</p>	FAA should confirm the suitability of a reduced (2 dB vs 6 dB) safety margin for helicopter low altitude banking and pitch operations.	17Nov2016: Difference of opinion: Ligado's perspective (per Ligado's interpretation of the ABC methodology document - 2014) is that the probabilistic limit addresses the banking cases and mean power limit does not apply for banking operations (for purposes of assessing compliance). WG6 perspective is that both mean and rare power limit apply for banking operations.	Need to discuss the 2dB banking case from the perspective of mean aggregate vs the probabilistic modeling. Offline discussion was held on 11/4/2016. Some of the participants are: Ligado, Sai, John Foley, Bob Erlandson, Ken Peterson, Ken Alexander, Andrew Roy.	Provide feedback from SC-159, WG6 per Resolution column.
13	John Foley	3.0 item 2.a	8	<p>The submission relates solely to certified Garmin GNSS aviation equipment:</p> <p>The descriptions of the parameters used to compute the aggregate RFI for scenario 1 is confusing, particularly the vague text in footnote 8 that states the central tower was different from the adjacent towers.</p>	Clarify the conditions used to generate the results for scenario 1.		Ligado to provide additional clarification note. Ligado provided a response to this on 8Nov16.	Item closed

14	John Foley	3.0 item 2.a.ii	8	<p>The submission relates solely to certified Garmin GNSS aviation equipment:</p> <p>Ligado proposes the use of a 1.8 dB reduction from peak azimuthal antenna gain when determining aggregate interference effects. This is intended to represent the average base station antenna gain. Ligado references the FAA Methodology and Assumptions document as the basis for this 1.8 dB gain reduction.</p> <p>However, the FAA Methodology includes a probabilistic component to account for variations in the received power. The Ligado method does not appear to include any probabilistic aspects in determining the aggregate RFI, so it would appear that using the average antenna gain may not be sufficient to ensure aviation safety.</p> <p>Since the aggregate interference analysis is intended to determine the maximum aggregate interference that could be seen by an aircraft operating near any Ligado base station, reducing the base station antenna gain does not seem appropriate.</p>	Use the peak base station antenna gain to determine the maximum aggregate RFI.	FAA GPS ABC Study doc, Scn 3.1.2.1, para 2 has the 1.8 dB reduction reference.	Need to discuss the variation between the mean 1.8 dB reduction and the probabilistic variation around the same.	Item closed
15	John Foley	3.0 item 2.a.ii	8	<p>The submission relates solely to certified Garmin GNSS aviation equipment:</p> <p>How is the aircraft ground control point chosen for the multi-tower RFI calculations? The selection of this point seems like it would affect the set of distances that are evaluated for aggregate interference.</p>	Clarify how the aircraft ground control point is chosen and what impact that has on the aggregate RFI results.	resolved		Item closed. Need more close out info on this item.

16	John Foley	3.1	10	<p>The submission relates solely to certified Garmin GNSS aviation equipment:</p> <p>Ligado assumes dual polarization for the base station transmissions, with half the total EIRP split for each.</p> <p>The FAA methodology assumes only vertical polarization for analysis of RFI to in-flight aircraft from ground base stations.</p>	Provide justification for the assumption of dual polarization for the base station emissions.	<p>Ligado: Design of transmit system aims to have equal power on H and V polzn. WG6 recommends that this be an FCC license restriction.</p> <p>Ligado has evaluated the power levels at and beyond the boundary of the cylinder to ensure that the power levels are not violated at and beyond the 250 ft cylinder threshold.</p>	V and H Pol assumed for MIMO operations - Ligado to provide rationale for this assumption. Ligado provided response and group reviewed the same on 10Nov2016. A follow on action for Ligado to clarify that the power levels were at the boundary of the cylinder and beyond. Ligado to provide additional text to this end (11/10/16).	Item closed
17	John Foley	4.1 item 2.d	14	<p>The submission relates solely to certified Garmin GNSS aviation equipment:</p> <p>The Ligado proposal references DO-301 as the source of the GPS antenna pattern. However, DO-301 doesn't provide the response relative to horizontal and vertically polarized signals, nor does it specify the lower hemisphere antenna pattern.</p> <p>Is the intent that the GPS antenna patterns specified in Appendix A, section A.2 of the FAA methodology and assumptions document be used for the analysis instead of DO-301?</p>	Clarify source of the GPS receive antenna pattern.	Ligado clarified that this is from the the FAA methodology and assumptions document		Item closed

18	John Foley	5.0	15-16	<p>The submission relates solely to certified Garmin GNSS aviation equipment:</p> <p>It appears that the limiting case driving the 0.9 dB backoff is in Example 2, with a 9 m base station height, a banked helicopter, and the 433 m intersite distance (6.2 BS/Sq.Km). However, this limit is not much different than the Example 1 case that used a larger intersite distance of 693 m (2.4 BS/Sq.Km), but with a variety of base station and GPS Rx parameters.</p> <p>Is there anything preventing the most stringent conditions in the Example 1 case from occurring with the 433 m intersite distance? Would this result in a larger required backoff for aggregate interference?</p> <p>Since the Ligado proposal allows for an intersite distance down to 433 meters, should the Example 1 cases also be evaluated at that distance?</p>	<p>Provide additional data of aggregate RFI if Example 1 used a smaller intersite distance. Garmin response on 11/16/16:</p> <p>Ligado's license should require that it modify the additional EIRP backoff to account for aggregate RFI from an urban macro cell deployment with a cell radius of 0.25km (433m ISD) and an antenna height of 25m, consistent with the smallest urban macro cell radius shown in Table 3 of ITU-R M.2292. Alternately, the license should include a condition to restrict base station antenna heights to 9m when the ISD falls below 693m</p>	<p>Consensus has not been achieved on this.</p> <p>Ligado: Any license restrictions should be deferred to the regulatory bodies.</p> <p>WG6: Garmin's proposal: Ligado's license should require that it modify the additional EIRP backoff to account for aggregate RFI from an urban macro cell deployment with a cell radius of 0.25km (433m ISD) and an antenna height of 25m, consistent with the smallest urban macro cell radius shown in Table 3 of ITU-R M.2292. Alternately, the license should include a condition to restrict base station antenna heights to 9m when the ISD falls below 693m</p>	<p>Ligado to review this further and get back to WG6. Potential to look at tying basestation distances to a range of antenna heights. Ligado responded to this on 11/10/16 and Garmin responded to the same on 11/16/16.</p>	<p>This was discussed further on 11/17/16 and Ligado has an action to respond to garmin's feedback from 11/16/16.</p> <p>SC-159, WG6 to provide feedback per the resolution column.</p>
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19	John Foley	5.1	16	<p>The submission relates solely to certified Garmin GNSS aviation equipment:</p> <p>There is no justification provided for why the Example 1 parameters will produce the maximum delta RFI. For example, only 4 of the Use Cases utilize the 25 deg bank angle. It is unclear why all of the Use Cases do not use both bank angles.</p>	Provide justification for the selected Use Case parameters.		<p>Ligado to provide additional results for 0 and 25 degree bank angles and 8 , 10 degree downtilt (Update to Example 1).</p> <p>"Ligado provided an update on 11/22/16: "Ligado WG-6 Responses 11-22-16.pdf". These responses were limited to the case of deterministic propagation modeling.</p> <p>Pursuant to discussions during the meeting, Ligado has the following actions:</p> <p>1) to provide more information on the propagation path losses vs radius for horizontal and vertical polarization components.</p> <p>2) provide all the details of the computation for one of the scenarios in the Nov 22, 2016 response to item 19 (Scenario 28).</p>	<p>Ligado response pending</p> <p>1) provide antenna data sheet with diff gains</p> <p>2) update table to capture the 25 deg banking analysis</p> <p>3) provide gains on direct and reflected rays for case 28</p> <p>4) use case 28, details with the 25 deg banking analysis.</p>
20	John Foley	Appendix 1	19	<p>The submission relates solely to certified Garmin GNSS aviation equipment:</p> <p>This section appears to be switching between cell density and base station density when determining the minimum intersite distance. It is unclear how the cell density of 2.2 BS/Sq. km is computed.</p>	Clarify computation of the cell density which is an input to the computation of the intersite distance.	Clarification provided	Clarify in the Appdx that the 433 m ISD translates into a given density of stations for a given hexagonal side value.	Item closed

21	John Foley	Appendix 2	21-26	<p>The submission relates solely to certified Garmin GNSS aviation equipment:</p> <p>The base station antenna pattern on page 26 provides only one example of a base station antenna that might be used in the Ligado network.</p>	<p>Obtain explanation for the selection of the base station antenna pattern used in the Ligado method. Clarify whether or not the base station antenna pattern will be updated when determining the baseline reference power for an individual cell site (Step 1 of the Ligado method). Evaluate whether the Ligado method adequately addresses the use of other antennas.</p>	<p>Ligado to provide clarifying note in regard to antenna pattern assumptions on analysis for aggregate backoff vs specific patterns for single basestation calculation. Response provided by Ligado in 11/8/16 feedback.</p>	Item closed
22	WG6 - various	Exec Summary	2	<p>How is the 250 ft. standoff cylinder minimum radius justified? It seems that the RTCA TOC did not recommend any min. radius</p>	<p>Provide detailed technical justification</p> <p>Consensus has not been achieved on this item. Ligado perspective: Evidence suggests that emissions into the GNSS band from other sources are in excess of the RTCA criteria. WG6 perspective: There is no conclusive evidence from the data presented that we have these higher levels of OOB from PCS and other sources in the GNSS band.</p>	<p>Ligado to provide updated information on the OOB emissions from other cell sources into the GNSS band at L1. Ligado to include relevant points for the technical justification of the 250 ft standoff radius. Ligado provided response on 11/8/16.</p>	<p>Provide feedback from SC-159, WG6 per resolution column</p>

23	WG6 - various	3.0	7	Why was the Ligado downlink propagation modeled using a deterministic two-ray model while the uplink was modeled assuming a probabilistic propagation environment?	The downlink interference scenario should be redone using the probabilistic propagation model outlined in the RTCA ABC study document as both the mean power limit and the so-called rare limit imply that such a model be used.	Consensus has not been achieved. Ligado: In conjunction with the response for item 12, the methodology utilizes a use case based conditional probability of the helicopter being at the most vulnerable point on the standoff cylinder. WG6: The conditional probability approach (per interpretation of the ABC methodology doc) is not applicable for this case.	Ligado to provide write up that explains the rationale used for the deterministic modeling for review by WG6. Ligado provided feedback on 11/16/16.	Provide feedback from wg6 per resolution column.
24	WG6 - various	3.0	8	Table 1 lists the RFI limit for the banking orientation as -30.1 dBm (rare condition at 10^{-6} prob.) while banking is a normal flight orientation	Revise for proper mean and rare condition limit application. See related KMP, RJE comment for Sec. 3.0 pg. 7	Consensus has not been achieved Please see responses to items 12 and 23	See item 12, plan to have meeting before end of week (11/4/16)	Provide feedback from wg6 per resolution column.
25	WG6 - various	4.1.2	15	Report ITU-R M.2292, referenced for the 0.43 km small cell, seems to also cover the larger cell example in 4.1.1. Would those small cells be operated simultaneously with the larger cell surrounding them?	Provide a more complete explanation and, if necessary, a revised analysis	Consensus has not been achieved on this. Ligado: Freq reuse will preclude having a small cell network within a larger cell. Any license restrictions should be deferred to the regulatory bodies. WG6: Recommend that there be a restriction on the license similar to what was proposed in Line 18.	Ligado continuing to evaluate this and will provide more information to WG6 on the same once analysis is complete. Ligado provided additional feedback on 11/8/16 on item 20.	Provide feedback from wg6 per resolution column

26	Larry chesto	Overview (Power Control)		It is not clear how power is controlled. Is it fixed at each site or controlled by a computer.	If it is controlled by computer, then RTCA/DO-178 on software should be applied as it is for certified aviation receivers	Please see comment 35 (which mirrors this comment and adds to the same) for resolution	Ligado to provide write up to clarify this query (in terms of how the power is controlled, regulatory mechanism that determines compliance). Ligado provided response on 11/8/16.	Provide feedback from SC-159, WG6 per resolution column
27	Larry chesto	3.1 (Propagation)		Not sure why 2-Ray model is not applied when the distance exceeds the breakpoint distance.	It may not matter when the aircraft is in motion as the reflected signal strength will change. Rate of change depends on aircraft speed. In a stationary condition, one could have a Fresnel zone interference situation which is similar to the 2-Ray concept. In a communication system this is resolved by changing antenna height	Ligado's assumptions are more conservative and addresses this query		Item closed
28	Larry chesto	Overview (Antenna)		they can not use an existing antenna for this band of operation (1526-1536 MHz)	a low pass filter should be investigate that can be in front of antenna or integrated into the antenna. There are companies that custom design RF filters (e.g. Anatech Electronics). This would solve this complex problem	Please see comment 35 (which mirrors this comment and adds to the same) for resolution	Sai and larry to tie off on this.	Item closed

29	Gregory Baker		2	The RFI limit was not evaluated at the top of cylinder. An antenna with a poor upper side lobe suppression (For 90/65/45 degree beamwidths) or an omni antenna could radiate enough power to break the RFI Limit	RFI Limit is analyzed for antenna with poor USLS and Omni antennas	Ligado plans to comply at the entire boundary around the antenna	Ligado to provide data for the top surface of the standoff cylinder. Ligado provided data on 11/8/16	Item closed
30	Gregory Baker		9	2-ray model case only applies to reflected path with ground, not the top of the rooftop. A very common scenario in RF Deployment is in a rooftop mounted site where the antenna is mounted ~10-40 feet from the rooftops edge for mounting purposes or due to zoning	RFI Limit is analyzed for with reflection wave coming from rooftop	This is not expected to be the worst case scenario and is subsumed by the worst case scenario analysis (to be confirmed)		Item closed
31	Gregory Baker		17	Clarification on worse case antenna: Is it only limited to di-pole arrays? In a multi-beam antenna, is the power restricted per radio, or per antenna?		For MIMO net EIRP will be consistent with the commitment		Item closed
32	Gregory Baker	Ligado OOB updated 11/8/16		Emissions correlate to frequency response of spectrum analyzer and/or amplifier. For Radio #3 and Radio #4, the displayed power on the spectrum analyzer in the spurious region of the remote radio head, as well as the displayed power in the GPS L1 band, appears to be noise generated from the test equipment.	Clarify the OOB emission tests provided by Ligado are not related to the test equipment	Consensus not achieved. Ligado perspective: Evidence suggests that emissions into the GNSS band from other sources are in excess of the RTCA criteria. WG6 perspective: There is no conclusive evidence from the data presented that we have these higher levels of unwanted emissions (including OOB and spurious emissions) from PCS and other sources in the GNSS band.	Greg Baker: To present the calculations for radio head power level. Update - 11/17/16: Pls see "Power Calc - Greg Baker.pdf". Santanu to provide a short write up on what a cumulative -8 dBm OOB implies (for eg: a 48dBc w.r.t. carrier)	Provide feedback to SC-159, WG6 per resolution column, Consensus not achieved

33	Sai Kalyanaraman - Rockwell Collins			As applicable to civil certified GPS receivers, how does the 1e-3 threshold for the acquisition case at 6 dB below the tracking threshold get addressed in this proposal.	Please clarify how GPS acquisition cases are addressed by this proposal.	Consensus not achieved. Ligado Response: GPS Acquisition was not stated as a requirement per the original FAA tasking letter (2014 letter and RTCA response in 2015).		WG6 to Provide feedback per resolution column. Consensus not achieved
34	Various (Ref: WG-6 telecon 4 Nov 2016)	General Scope	N/A	Should scenarios related to receiver initialization/power-up/satellite acquisition be assessed that correspond to EMS helicopter operations to/from pick-up scenes (in addition to IAPs)? The scenario would define (a) if the receiver is generally powered up through the pick-up or if it must be assumed the receiver can be powered up and initialized at the scene, (b) what the receiver operating state is required to be before departing the pick-up scene, and (c) the need for the helicopter to support IFR operations at a specific time, altitude or distance from the pick-up scene and/or destination. EMS: emergency medical services, IAP: instrument approach procedure, IFR: instrument flight rules	Either (1) In concert with the RTCA TOC, define appropriate scenarios and assess compatibility with existing MOPS requirements and test procedures. – or– (2) Submit the comment to the FAA for their consideration.	Consensus not achieved, item not fully resolved. Do both items 1 and 2		WG6 to Provide feedback per resolution column.

35	Larry Chesto	General Scope	N/A	<p>1) Power control. Software security and Integrity. Ligado has action item on part of this. Is max TX power 60 W?</p> <p>2) There are 9 assumptions in Ligado paper and 4 ensures. Need to verify all assumptions and determine how everything is ensured.</p> <p>3) Acquisition and re-acquisition should be addressed. With all the increased noise in the 1559-1610 MHz band in a metro area, it is necessary to keep additional noise at a minimum.</p>	<p>Ligado approach appears to be in the correct direction. However, one should not base a conclusion on equipment data for other frequency bands. No final approval should be made by RTCA until the final specifications and tests of the system are available and can be analyzed by RTCA. Need actual specs and tests of equipment that will be used including transmitter and antenna.</p>	<p>This comment will be provided to the FAA as such. Consensus not achieved.</p> <p>Ligado: This will be addressed by Ligado in conjunction with the FCC prior to rollout of the network.</p> <p>WG6: Understanding that power control is being implemented in the networks (and is the norm for cellular network operations), the onus of ensuring that the transmit power level requirement is being met (at all times at the applicable probability threshold) so as to not interfere with certified safety of life operations needs to be taken into account in terms of design of the system (and relevant system monitors). This needs to be addressed as part of a license condition.</p>	WG6 to Provide feedback per resolution column.
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